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SOME FACTORS IN SWIMMING POOL CONTROL*

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The increase in popularity of public swimming pools and their installation as part of the equipment in nearly all departments of physical education has made the sanitary control of these pools an important problem.

As Mannheimer,[1] Levine,[2] Lewis[3], and others, have reviewed the literature adequately, it is not necessary to do so now. Mannheimer emphasizes the potential danger of swimming pools in the spread of disease.

For several years past it has devolved on the staff of the Wisconsin State Laboratory of Hygiene to conduct inspections and make recommendations for the control of the 2 pools at the University of Wisconsin. The pool for men has proved an especially interesting subject for investigation, both on account of its appointments and the large number of students who use it. This pool is located on the ground floor of the gymnasium, in the central part of the large locker room. On both sides of the shallow end of the pool are located the showers. The pool is not enclosed nor separated from the showers or lockers, but the contour is well above the general level of the floor of the room. The inside of the tank is lined, with the exception of a small square in the deep end, with white tile. The room is not well lighted. The water (Table 1) used in the pool is pumped directly from Lake Mendota and contains naturally much plankton life.

The results of 2 investigations of this pool constitute the material for this paper. The 1st was made to determine the effect of biweekly treatments with commercial chlorid of lime and copper sulphate, respectively, on the unfiltered lake water then in use; the 2nd and more extended investigation was made after the installation of a refiltration system.

CHEMICAL DISINFECTION

The first set of observations was done in the fall of 1915, at which time record was made of the effect of using raw lake water, water treated biweekly

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* Received for publication June 19, 1917.

[1] Jour. Infect. Dis., 1914, 15, p. 159.
[2] Ibid., 1916, 18, p. 293.
[3] Jour. of Indust. and Engin. Chem., 1916, 8, p. 914.

with copper sulfate, 0.5 part per million equivalent of the anhydrous salt, and commercial chlorid of lime equivalent to 0.5 part per million available chlorin, respectively. The results of this work are given in Chart 1.

TABLE 1

COMPOSITION OF THE WATER OF LAKE MENDOTA (ANALYSIS IN PARTS PER MILLION)

(a) Mineral Analysis[4]	
Silica	15.2
Aluminum and Iron Oxids	2.2
Calcium	19.8
Magnesium	21.6
Sodium	3.6
Potassium	2.2
Carbonate radicle	77.2
Sulphate radicle	15.3
Chlorine	3
(b) Sanitary Analysis	
Turbidity	0
Odor	0
Color	0
Nitrogen as free ammonia	0.044
Nitrogen as albuminoid ammonia	0.264
Nitrogen as nitrites	0.002
Nitrogen as nitrates	0.08
Hardness by soap method	185
Alkalinity by methyl orange	167
Oxygen consumed	3.3
Total solids	202

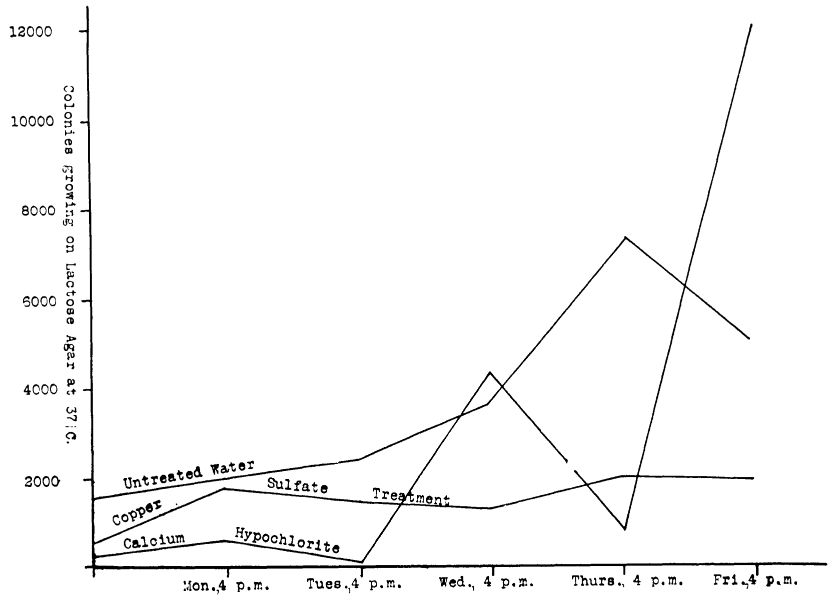

Chart 1. Effects of biweekly treatments

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[5] The mineral analysis is taken from "The Underground and Surface Water Supply of Wisconsin," Wis. Sur. Bull., 35, p. 299.

It will be noted that while copper sulphate did not reduce the count as much as chlorid of lime, its effect was more lasting. In other words, it appears that the copper is not dissipated as readily as the 'bleach.' The immediate rise in the bacterial count directly after the hypochlorite is spent is probably due to the disintegration and oxidation products left available for bacterial food by the action of the hypochlorite on the organic matter originally present and accumulated.

REFILTRATION

In the late summer of 1916, a refiltration system was installed, and in the fall of that year it became necessary to conduct a series of observations to determine the best way to operate the system to obtain a satisfactory pool of water. A sketch of the system is shown in Figure 1.

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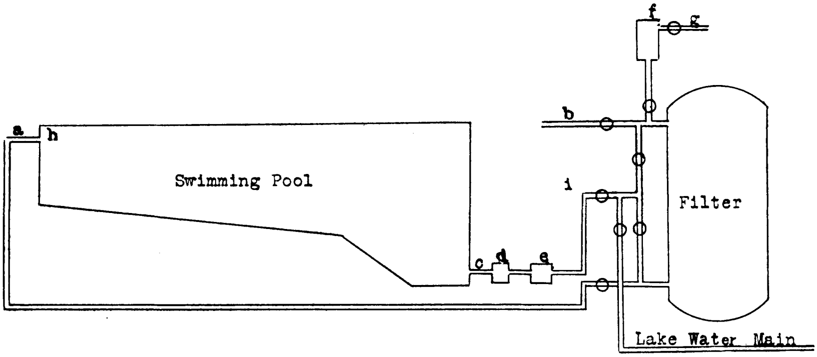

Fig. 1. Diagram of filter system (not drawn to scale). O = operating valves; a, inflow pipe to pool; b, pipe leading to sewer; c, outflow pipe to filter from pool; d, centrifugal pump; e, live steam heater; f, alum tank; g, city water main; h, place filtered sample taken; i, place unfiltered sample taken.

The problems were: Would refiltration alone under the conditions at this pool produce clear water and maintain a satisfactory bacterial count? Would it be necessary to use alum as a clarifier. Would it be necessary to treat the water in the tank with a disinfectant?

On Jan. 6, 1917, the tank was cleaned, filter washed, and tank refilled with filtered lake water without the use of alum. At noon, on January 8, the refiltration system was started and run 14 hours daily during the week. No alum or disinfectant was added during this week. The results are given in Table 2 (a).

TABLE 2

REFILTRATION

	Number of Colonies Growing on Agar,* at 37 C.		
Day of the Week	Unfiltered	Filtered	Tank
(a) Results for week beginning Jan. 8, 1917.			
Mon., p. m.	5	7	13
Tues., p. m.	4000	3000	2000
Wed., p. m.	1000	850	800
Thurs., p. m.	510	400	450
Fri., p. m.	1575	865	1100
(b) Results for week beginning Jan. 15, 1917.			
Mon., p. m.	108	125	113
Tues., p. m.	125	105	125
Wed., p. m.	200	130	170
Thurs., p. m.	250	165	170
Fri., p. m.	100	65	70
(c) Results for week beginning Jan. 22, 1917.			
Mon., p. m.	110	80	135
Tues., p. m.	80	40	60
Wed., p. m.	60	26	55
Thurs., p. m.	82	70	60
Fri., p. m.	45	50	45

* The agar used in this work was the standard litmus lactose agar.

During the next week, beginning January 15, the water from the week previous was left in the tank and treated with alum just before it entered the filter. No disinfectant was used but the refiltration system was operated 14 hours each day, as during the week before. The results are given in Table 2b. In the 3rd week, beginning January 22, both alum and commercial chlorid of lime were added each day. The latter was added directly to the pool in chlorid equivalent of 0.5 part per million. The results of this week are found in Table 2 (c). Table 2 (a) clearly shows that the filter was not satisfactorily removing the bacteria, and Table 2 (b) and (c) shows a low bacterial count in all samples, but a comparison of the unfiltered, filtered, and tank samples shows very little difference in the counts. The water in the tank was much clearer the last 2 weeks. During the 2nd and 3rd week of this series, alum in finely divided condition was detected in the tank sample, as well as in the other 2, filtered and unfiltered. The presence of alum in the tank water and the subsequent sedimentation caused thereby may in a measure explain the relatively few bacteria present in the water from the beginning of the 2nd week, for the filter showed no increase in efficiency. During the 2 weeks of alum treatment it was found necessary to remove the products of sedimentation with the vacuum cleaner 2 or 3 times a week in order to have a presentable tank of water.

The frequency which bacteria of the coli group were found to be present during these 3 weeks are given in Table 3.

TABLE 3

FREQUENCY OF B. COLI DURING 3-WEEK PERIOD, JANUARY 8-29, INCLUSIVE

Amount Water, C.c.	First Week, %	Second Week, %	Third Week, %
10	93	60	66
1	21	6.6	6.6
0.1	0	0	0

During this test period of 3 weeks, chemical determinations were made for the content of nitrite and nitrate nitrogen and the chlorin as chlorids (Table 4).

TABLE 4

CHEMICAL RESULTS

	Unfiltered			Filtered		
Day of the Week	NO_2	NO_3	Cl	NO_2	NO_3	Cl
(a) Results for week beginning Jan. 8, 1917						
Mon........	0.001	0.1	2	0.001	0.08	2
Tues........	0.002	....	2	0.002	....	2
Wed........	0.003	0.08	2	0.003	0.08	2
Thurs.......	0.004	0.14	2.3	0.004	0.16	2.2
Fri..........	0.006	6.4	2.2	0.005	4	2
(b) Results for week beginning Jan. 15, 1917						
Mon........	0.017	0.9	2	0.016	1.5	2.4
Tues........	0.052	0.24	2.8	0.035	0.24	2.5
Wed........	0.065	1.4	2.8	0.055	1.28	2.2
Thurs.......	0.104	0.4	2.5	0.122	0.24	2.5
Fri..........	0.208	2.63	2.8	0.208	1.85	2.8
(c) Results for week beginning Jan. 22, 1917						
Mon........	0.63	0.14	2.5	0.63	0.14	2.5
Tues........	0.8	0.18	3	0.8	0.18	3.1
Wed........	0.9	0.14	3.6	0.9	0.14	3.5
Thurs.......	1	0.18	4	1	0.18	4.2
Fri..........	1	0.2	5	1	0.24	5

It is seen that while there is some variation in the nitrogen as nitrates and the chlorin as chlorids, it appears that the only significant variation from the normal is the gradual rise in nitrite nitrogen. This we find gradually increasing 0.001-1 part per million. The methyl orange alkalinity showed a slight decrease during the last 2 weeks of the 3.

During the 3 weeks beginning Feb. 26, 1917, tests were made on the pool using copper sulphate as the disinfectant. During this series the water was changed each week and the filter was kept running about 14 hours each day. On Saturday, February 24, the tank was cleaned and the filter was washed, and the tank subsequently filled without the use of alum. On Tuesday and Thursday evening, at 8 p. m., copper sulphate crystals were added in the quantity of 0.5 part per million. The results of this week are found in Table 5 (a).

TABLE 5

CHEMICAL RESULTS

	Number of Colonies Growing on Agar, at 37 C.		
Day of the Week	Unfiltered	Filtered	Tank
(a) Results for week beginning Feb. 26, 1917			
Mon., p. m......................	300	1000	800
Tues., p. m......................	820	1500	480
Wed., p. m......................	170	35	3500
Thurs., p. m.....................	75	5	950
Fri., p. m.......................	175	....	175
(b) Results for week beginning Mar. 5, 1917			
Mon., p. m......................	1200	40	160
Tues., p. m......................	2500	1900	770
Wed., p. m......................	1200	205	950
Thurs., p. m.....................	900	450	750
Fri., p. m.......................	300	1000	410
(c) Results for week beginning Mar. 12, 1917			
Mon., p. m......................	3000	....	4500
Tues., p. m......................	1700	3100	1300
Wed., p. m......................	2500	525	1270
Thurs., p. m.....................	2400	175	300
Fri., p. m.......................	800	550	750

On Saturday, March 3, the tank was again emptied and cleaned, the filter washed, and the tank filled without the use of alum. Beginning Monday, March 5, there was added each day 0.5 part per million of copper sulphate crystals. The results of the week are given in Table 5 (b). Again on Saturday, March 10, the tank was prepared, the filter washed, and the tank filled without the use of alum. On each day during this week, copper sulphate crystals equivalent to 0.5 part per million of the anhydrous copper sulphate were added directly to the pool, as before. The results of this week are shown in Table 5 (c). The total amount of copper sulphate crystals entering the pool during each of these 3 weeks is:

First week	314 gm.
Second week	1100 gm.
Third week	1720 gm.

Note the variation in the count as shown in these tables under the title of 'tank'. During the 1st week, that of the biweekly treatment with copper sulphate, the high count was in the middle of the week and was about 4½ times the initial count on Monday. During the 2nd week, the high count was again in the middle of the week, and about 6 times the initial count on Monday. Contrasting these 2 results with that of the 3rd week—daily treatment with 0.5 part per million equivalent of anhydrous copper sulphate—the high count was here found in the beginning of the week, and was about 3½ times as large as on any other day. This appears to show that copper sulphate, when present in sufficient quantity, produces a satisfactory reduction in the bacterial count.

During the week beginning March 5, complete sanitary chemical determinations were made. The results are given in Table 6.

TABLE 6

SANITARY CHEMICAL RESULTS ANALYSIS IN PARTS PER MILLION

	Mon.	Tues.	Wed.	Thurs.	Fri.
Turbidity	0	0	0	0	0
Odor	0	0	0	0	0
Color	0	0	0	0	0
Nitrogen as free ammonia	0.044	0.152	0.140	0.252	0.216
Nitrogen as albuminoid ammonia	0.264	0.292	0.268	0.282	0.695
Nitrogen as nitrites	0.002	0.006	0.007	0.010	0.010
Nitrogen as nitrates	0.08	0.10	0.40	0.08	0.10
Chlorin as chlorids	1.5	2	2.5	2.2	2.5
Alkalinity as $CaCO_3$	167	165	163	155	161
Total solids	202	206	214	230	214
Oxygen consumed	3.3	3.3	4.4	4.3	4.6

Table 6 shows that the nitrogen as ammonias gradually increases from 0.3 to about 0.9 part per million, and that the nitrites are also found to increase, as shown in Table 5.

On March 17, a few supplementary experiments were undertaken, the first of which was to determine the effect of sterilization of the filter in the evening, after it had been running 14 hours. On March 19, at 6 p. m., the filter was washed, and 7 parts per million of chlorin as commercial chlorid of lime were added to the water in the filter and allowed to stand over night. A similar sterilization was conducted on March 20. On Wednesday and Thursday evenings, March 21 and 22, similar experiments were made, except that 9 parts per million of copper sulphate crystals were used. The results are shown in Table 7.

On Wednesday and Thursday morning, after the treatment with hypochlorite and copper sulphate, respectively, it is seen that the condition of the water as it leaves the filter is satisfactory. While it is difficult to see just why the 1st treatment with hypochlorite on Monday, the 19th, and the

1st treatment with copper sulphate on Wednesday did not produce as good results, it appears that such sterilization is worthy of application, especially if the filter has been standing idle for some time.

TABLE 7

EFFECT OF STERILIZATION OF FILTER

Day of the Week	Number of Colonies per C.c., Growing on Agar, at 37 C. Unfiltered	Filtered
Mon., p. m.	1050	9000
Tues., a. m.	5500	2750
Tues., p. m.	9000	900
Wed., a. m.	10	0
Wed., p. m.	110	235
Thurs., a. m.	2500	2000
Thurs., p. m.	2200	1250
Fri., a. m.	7000	25
Fri., p. m.	1250	200

On Saturday, March 31, the tank was prepared and the filter cleaned, as in previous experiments. The plan for this week was to start with a tank of filtered water and to note the effect of disinfection without refiltration. This corresponds to the treatment as shown in Chart 1, with the exception that in this latter test filtered lake water was used, while in the former unfiltered lake water was used. Accordingly, the tank was slowly filled from Saturday, March 31, to Monday, April 2, with the use of alum. At 8 p. m. on Tuesday, the pool was treated with 0.7 part per million chlorin as hypochlorite, and a similar treatment on Friday morning, at 8 o'clock. The results are shown in Table 8.

TABLE 8

EFFECT OF DISINFECTION WITHOUT REFILTRATION

Week beginning April 2, 1917

Day of the Week	Number of Colonies per Cc., Growing on Agar, at 37 C. Shallow	Deep	Average
Mon., a. m.	60	60	60
Mon., p. m.	175	220	198
Tues., p. m.	2000	1700	1850
Wed., p. m.	450	220	335
Thurs., p. m.	3000	2250	2625
Fri., p. m.	25	9	17

These results are interesting when compared with the results as shown in Chart 1.

STERILIZATION OF THE FILTER

It appears possible that the filter may act in a manner not altogether unlike a septic tank, inasmuch as conditions are favorable for such action, when it is allowed to stand idle several hours a day. The first indications which we noticed of such action was the stench which accompanied the water from the washings of the filter after the filter had not been used for a few days, and that frequently the filtered sample contained more bacteria than the unfiltered or tank samples. On one of these occasions the filter was washed in the usual manner, and then chlorin as hypochlorite was added to the strength of about

7 parts per million, directly on to the filter. Samples were taken of the untreated and treated water and the counts made. The results are given in Table 9. It is seen that the action of the chlorin is very rapid, probably instantaneous, as the time factor recorded is evidently largely dependent on the mechanical factor of mixing, which in the case of the stationary filter is obviously slow.

TABLE 9

EFFECT OF TREATING FILTER WITH HYPOCHLORITE

	1 C.c. on Agar, at 37 C.	1 Cc. on Gelatin, at 20 C.
Before treating	2500	30000
½ min. after treating	35	3750
3 min. after treating	10	1250
10 min. after treating	20	325
30 min. after treating	0	0

The first sample was taken from the wash water at beginning of the washings.

EFFICIENCY OF THE FILTER

From Tables 2 and 5 an idea may be obtained concerning the efficiency of the filter. In no instance does the difference in the bacterial counts in the unfiltered, filtered, and tank samples indicate that the filter alone can be relied on to satisfactorily remove bacteria, and that in some instances the filter seems to actually pollute the water. This latter is noted particularly after the filter has been washed, or after it has stood idle for some time without being washed.

If the efficiency is calculated by a comparison of the total bacteria in all of the unfiltered and filtered samples, then it is found to be 28.9% efficient. The efficiency is found to be 25% when calculated from the frequency with which bacteria of the coli group are found, using 40 10 c.c. samples for the calculation. These calculations, however, are obviously misleading, because at times the filter shows a negative efficiency. It does not constantly produce these percentages of efficiency, and, therefore, can not be relied on.

Tables 2 and 5 further seem to show that the use of alum has by some means reduced the bacterial counts in all of the samples. It was used by adding it to the water just as the water went on to the filter, hoping that the formation of aluminum hydroxid from the alkali and alkali earth corbonate in solution would clog the filter sufficiently to produce a material reduction in the bacterial count of the effluent. It did not do this. The water in the tank, however, was much clearer. This result is probably explained by the fact that the alum either passed through the filter in a finely divided state, or in solution afterwards to form the hydroxid, and precipitated out in the tank during the night, carrying down much dirt and many bacteria. Such a conclusion is certainly substantiated by finding finely divided aluminum hydroxid in the water in the tank, the low bacterial counts, Table 2 (b) and (c), in all the samples, unfiltered, filtered, and tank, and by the presence every morning of much dirt on the bottom of the pool.

CONCLUSIONS

It appears from the studies of this pool that refiltration alone cannot be depended on to deliver a satisfactory tank of water. The initial filtration of the water appears to be of decided value in that it removes some of the suspended matter present in the raw lake water.

If refiltration is to be used it appears advisable to operate the filter continuously for 24 hours. If there is to be an idle period of several hours, the filter should be washed before the pump is stopped, and the filter treated with some disinfectant.

In conjunction with refiltration, it appears necessary to treat the water in the tank with either chlorin or copper sulphate in order to insure at all times a safe pool of water.

From the frequency with which alum was found passing through the filter, it seems advisable to pump the water through a coagulation basin before it enters the filter. This will give time for reaction, flocculation, and coagulation in particles large enough to 'clog' the filter and raise the efficiency from the beginning.

A vacuum cleaner should be a part of the equipment of the swimming pool.

The point of safety for the bathers can be as well secured by 1 initial filtration and subsequent treatment with either chlorin or copper sulphate, using a freshly filtered tank of water every week, as with refiltration and treatment, using the same tank of water for several weeks.